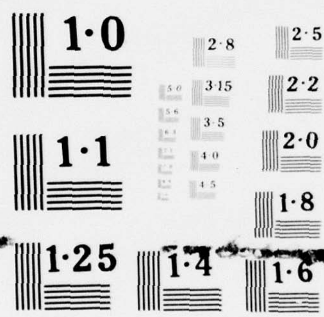
AD-A043 348 AERONAUTICAL RESEARCH LABS MELBOURNE (AUSTRALIA) F/G 1/2
THE USE OF WRECKAGE TRAJECTORIES IN AIRCRAFT ACCIDENT INVESTIGA--ETC(U)
MAY 76 J L KEPERT
UNCLASSIFIED ARL/STRUC. 427 NL

1 OF 1
AD
A043 348

END
DATE
FILMED
9-77
DDC




NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

 ARL/Struc. Note 427

1



AUSTRALIA

# DEPARTMENT OF DEFENCE

## DEFENCE SCIENCE AND TECHNOLOGY ORGANIZATION

## AERONAUTICAL RESEARCH LABORATORIES

MELBOURNE VICTORIA

## Structures Note 427

# THE USE OF WRECKAGE TRAJECTORIES IN AIRCRAFT ACCIDENT INVESTIGATION

by

J. L. KEPERT







MAY 1976

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANIZATION

AERONAUTICAL RESEARCH LABORATORIES

(14) ARL/Struc. 427

(9) STRUCTURES NOTE 427

(6)

# THE USE OF WRECKAGE TRAJECTORIES IN AIRCRAFT ACCIDENT INVESTIGATION

By

(10) J.L. KEPERT

(11) May 76 (12) 21p.

*SUMMARY*

*This paper examines the characteristics of aircraft wreckage layouts obtained after an in-flight break-up and discusses the use of these data in accident investigation.*

*Procedures are developed for the determination of some relevant parameters such as the position and altitude of break-up. The paper mentions some of the problems which may be encountered and emphasises that the analysis of aircraft wreckage trajectories should be considered additional to, rather than a substitute for, more conventional accident investigation techniques.*



008 650

CONTENTS

## 1. INTRODUCTION

Whenever an aircraft breaks up in the air, either completely or in part, the wreckage is scattered over a relatively wide area. The number of wreckage items will depend upon the extent of break-up which, in turn, is dependent upon the nature of the damage sustained by the aircraft. For example, extensive break-up will normally result from mid-air collisions, internal explosions, fuselage failures, etc. while wing failure, engine disintegration, etc. may lead to only a limited degree of break-up. In many instances an aircraft will survive a limited degree of break-up such as that associated with fin failure or engine separation. However, even in these instances it is most unusual for the detached material to be confined to a single wreckage item.

During any investigation into an aircraft accident, it is customary to plot the ground layout of the wreckage as it is recovered. This is invariably the case when mid-air break-up is suspected. From this ground layout it should be possible to determine certain parameters of the aircraft, particularly speed and altitude, at the time of break-up by calculating the trajectories of selected wreckage items and plotting these back from the ground layout. The point of intersection of the calculated trajectories is then identifiable in space as the point of break-up. If a succession of intersections can be established, these will give an indication of the break-up sequence.

This paper gives details of the approach adopted by A.R.L. in the analysis of aircraft wreckage trajectories. This approach is based on data obtained from various trials at Woomera, Australia, and is confined to cases where break-up occurs at altitudes of less than 3000m (10,000 ft.).

## 2. TRAJECTORY ANALYSIS

In zero-wind conditions, the acceleration of a body in free fall is

horizontally, $\dfrac{d}{dt}(v \cos \theta)$

vertically, $\dfrac{d}{dt}(v \sin \theta)$

where $v$ = speed
$\theta$ = angle between the tangent to the trajectory and the horizontal
$t$ = time

Hence,

horizontally, $$-F \cos \theta = m \frac{d}{dt}(v \cos \theta) \qquad (1)$$

vertically, $$mg - F \sin \theta = m \frac{d}{dt}(v \sin \theta) \qquad (2)$$

where $m$ = mass of the body.

The aerodynamic drag, F, is given by,

$$F = m k v^2$$
$$= \tfrac{1}{2} \rho v^2 \bar{A} C_D$$

where $\bar{A}$ = mean presented area of the body.
$C_D$ = aerodynamic drag coefficient.

These equations may be used for calculating the trajectory of any wreckage item having the initial conditions $V_o$ and $\theta_o$. The accuracy of the results obtained will depend upon the accuracy of the input data and on the significance of any effect not included in the analysis.

The analytical approach has a number of inherent difficulties associated with it. The initial velocity of some wreckage items may not be the same as the aircraft speed but may have some additional velocity input. This is obviously true of rotating engine parts but may also apply to structural items in the event of internal explosion, severe turbulence, etc.

A more serious difficulty arises in the assessment of aerodynamic drag. A piece of wreckage may fall in a stable or unstable mode. It may streamline, oscillate or tumble depending upon its mass distribution and aerodynamic characteristics. It may have more than one stable mode.

Attempts to guess a reasonable drag coefficient for individual wreckage items are unlikely to result in reliable estimates since tests indicate that the drag coefficient of visually similar wreckage items may differ by a factor of up to 10.

Experiments conducted to determine the aerodynamic drag of selected wreckage items suffer the difficulty that it is impossible to be sure that the mode of fall exhibited during the experiments is the same as that which occurred during the accident. Mounting a wreckage item in a horizontal wind tunnel will always impose constraints which may generate an artificial mode of fall. Moreover, the wreckage item under test is not identical with the item which fell during the accident since it will have been modified, to at least some extent, by the intervening ground impact. Free fall experiments on wreckage items are not reproducible for the same reason. A series of such experiments conducted on a single wreckage item will tend to give variable results since the wreckage is constantly being modified by ground impact damage.

A further difficulty with this approach is that a falling piece of wreckage may develop aerodynamic lift, i.e. the item may be subjected to an aerodynamic force normal to the direction of motion. This force is not included in the basic equations since it is extremely difficult to estimate its magnitude and out-of-plane component which, again, will depend upon the mode of fall. Attempts to measure aerodynamic lift suffer from the same difficulties as those associated with the measurement of aerodynamic drag.

The final difficulty concerns wind drift. As stated earlier, equations (1) and (2) are for zero-wind conditions. However, these conditions rarely, if ever, exist in practice and the wind profile in the accident area must be known if the calculated trajectories are to be modified with precision.

Some investigators, including A.R.L., have endeavoured to use the analytical approach in the past, either with or without an experimental determination of aerodynamic lift and drag, using selected wreckage items. In an effort to eliminate the uncertainties associated with wreckage items which exhibit a stable mode of fall, some investigators have rejected all such items and concentrated solely on wreckage items which fall in an unstable mode. Frequently, in an attempt to minimise the effect of ground impact damage, attention is concentrated on wreckage items which have a low terminal velocity. It is argued that the ground impact damage to such items will be insignificant. The problems with this approach are that many significant wreckage items are simply ignored and that attention tends to be concentrated on small light items which satisfy the above requirements, e.g. aluminium skin, perspex, fibreglass, etc. Such items are heavily influenced by wind drift and the problem tends to be dominated by the estimation of wind profile. Moreover, since all such items lie downwind from the break-up point, the calculated trajectories lie on or near a single vertical plane with trajectory intersections confined to that plane. Thus, a three dimensional problem is tackled two-dimensionally with a consequent decrease in accuracy. In general, these attempts have not been particularly successful due to the low level of confidence in the results obtained.

## 3. WOOMERA TRIALS

Since 1958, A.R.L. has examined the wreckage of every target aircraft destroyed or damaged in missile trials at Woomera. Most of these trials have involved the in-flight break-up of the target aircraft. Additional data are available from some target development trials which have terminated in the in-flight break-up of the aircraft. In all cases, the speed, flight path and altitude of the target aircraft are known to a high degree of accuracy, detailed meteorological data are available and accurate ground plots of the target wreckage have been compiled. In some cases, radar plots of, and reduced trajectory data for, major items of wreckage are available for some time after break-up although these data generally terminate before ground impact. Thus Woomera trials provide a large body of data suitable for the study of aircraft wreckage trajectories. The data have been generated under carefully controlled conditions, are highly accurate and probably unique.

Before these data can be used in the development of general analytical methods or empirical procedures, it is necessary to examine their applicability to the general field of aircraft accident investigation. The target aircraft used at Woomera are unmanned Jindiviks, Meteors and Canberras. Structurally, these aircraft belong to what may be termed the World War 2 generation of aircraft. That is, they belong to the generation of aircraft having all metal aluminium alloy structures, of riveted or bonded construction, and characterised by relatively thin skins in association with heavy discrete structural elements such as wing spars, fuselage longerons, etc. Many aircraft currently in manufacture, including most light aircraft, fall within this structural

generation. The break-up of any aircraft of this structural generation can be expected to produce similar wreckage, i.e. the general characteristics of wreckage are common to a structural generation and independent of aircraft type. This is another way of saying that, in general, wreckage items do not possess characteristics which are peculiar to an aircraft type.

The application of Woomera trials data to aircraft of different structural generations should be avoided. Clearly, the wreckage produced by a Meteor will be very different from that produced by a Tiger Moth (typical of the 1920's structural generation) or by an F.111 (the supersonic generation). The fact that target aircraft are unmanned should not affect the issue since wreckage characteristics are not dependent on the actions of a pilot.

## 4. USE OF TRIALS DATA

As mentioned in Section 2, A.R.L. initially attempted to use Woomera trials data in support of the analytical approach. The results obtained showed considerable inconsistency; in some cases trajectory analysis gave good results, in other cases the results were very poor. It was clear from this work that it was impossible to attach any confidence to the results obtained and the work was abandoned.

Subsequently, as an integral part of other tasks, it was necessary to use some of the data to determine the ground impact points of aircraft and missile wreckage following mid-air break up. It was decided to develop a comparative procedure based on purely empirical rules and to use this procedure in preference to the analytical approach. This procedure was developed and has since been used, with success, for various ad-hoc tasks.

## 5. A.R.L. PROCEDURE

The A.R.L. procedure was developed around the philosophy that all wreckage items are of importance and each can make some contribution to the total picture that emerges. The final picture should be consistent and compatible with all wreckage items. This philosophy recognised that the analytical approach, in working from a few selected items only, tended to disregard too much evidence and to place too much reliance on a small minority of items which may or may not have been a truly representative sample.

From an inspection of the trials data, it was clear that all wreckage items could be considered in three groups, viz. light, medium and heavy. The characteristics of these groups are discussed in the following sections.

### 5.1 Light Wreckage Items

Light items are characterised by a low weight/surface area ratio and consist of aluminium sheet or extruded angle material, perspex, fibreglass, etc. They lose all their forward velocity shortly after separation from the aircraft and their trajectories are essentially determined solely by wind drift. Thus light items lie downwind from the break-up point but, because of vagaries in the wind, they are scattered about the line of the mean wind. Experience has shown that all light items are generally contained within a sector with apex at the break-up point and with an apex angle of 30°. The sector is located downwind of the break-up point and oriented so that its centre line is coincident with the line of the mean wind; see Fig. 1. This 30° sector contains all of the light items which separated at the break-up point; any light item not contained by the sector separated at some other time. Clearly, if break-up proceeds in stages such that there are n points of successive partial break-up, then there will be n sectors corresponding to these break-up points; see Fig. 2.

### 5.2 Heavy Wreckage Items

Heavy items have a high weight/surface area ratio and consist of engines, batteries, undercarriage legs, etc. They are little affected by wind drift and their trajectories depend primarily on the velocity of the aircraft at the time of break-up. Such items are recovered from points lying close to the line of the extended flight path of the aircraft. Because heavy items may develop significant aerodynamic lift during their fall, some random aerodynamic dispersion will occur and, on average, the items will be evenly distributed about the extended flight path; see Fig. 1. Wind drift will introduce some bias to this distribution but this is generally small in comparison with aerodynamic dispersion. Thus, a mean line drawn through the ground impact points of heavy items will define the extended flight path of the aircraft with sufficient accuracy. The heavy item sector will be positioned symmetrically about this mean line with apex at the break-up point.

### 5.3 Medium Wreckage Items

Medium items are those which have trajectories which are influenced, in varying degree, by both wind drift and forward velocity. They will be located in a sector downwind of the extended flight path and forward of the break-up point. As shown in Fig. 1, this sector is bounded by the forward limit of the light wreckage sector, the downwind limit of the heavy wreckage sector, and some concave curve running between the extreme heavy and light items.

### 5.4 Determination of Break Up Point

By applying the concepts contained in the preceding sections, the break-up point can be established with reasonable accuracy. The direction of the mean wind and the flight path of the aircraft at break-up will also be established. In the process, a good idea will be obtained of the break-up sequence if that sequence was sufficiently prolonged for wreckage to be scattered over a significantly greater area than would have been the case with instantaneous break-up; see Fig. 2. That is to say, it is generally not possible to distinguish between instantaneous break-up and short period break-up; a break-up sequence must extend over a relatively long period for the sequence to be identified.

A good example of the way in which the correct identification of the break-up sequence can help determine the cause of an accident is provided by Jindivik A92-413 which broke up in the air at Woomera on 19th February, 1965. A plot of the ground layout of the wreckage from this accident is shown in Fig. 3. In the initial accident investigation, Ref. 1, this plot was interpreted as indicating that break-up was initiated by failure of the fin since wreckage items furthest from the aircraft flight path were pieces of the fin.

The investigation of subsequent Jindivik accidents with similar features led to a re-investigation of the accident to Jindivik A92-413. While following the A.R.L. procedure, it was appreciated that the underwing fairing was the first item to separate from the aircraft and that this occurred some 3.5 to 4.0 seconds before general break-up. For the fairing to separate in this way, a gross deflection of the fuselage in bending is required. This could only have occurred as a result of flutter and flutter was advanced as the most likely cause of the accident. A subsequent analysis of the body freedom flutter characteristics of the Jindivik aircraft confirmed flutter as the cause of the accident.

## 6. SOME PROBLEMS

It is worthwhile, at this stage, to mention some of the problems which may be encountered in determining the break-up point. Some wreckage items may be recovered from positions which are, apparently, incompatible with any reasonable picture which may be developed. Before attempting to modify the picture, such items should be examined carefully to ascertain whether some *additional factor* may be involved in determining their final location. They may have received some additional impetus as a result of internal explosion, engine disintegration, collision, etc. An example of this effect is provided by the collision between a missile and Meteor A77-207 at Woomera on 18th. November, 1971. The Missile struck the port engine of the aircraft and, as a result of the impetus they received during the collision, pieces of the port engine ultimately landed in a region behind the target break-up point, Fig. 4.

Another example is provided by D.H. Dove VH-WST which broke up after colliding with Piper Twin Comanche VH-WWB on 13th. March, 1974. The port propeller of the Twin Comanche separated from the engine and was recovered from a position well to the left, i.e. upwind, of the extended flight path of the aircraft, Fig. 5. A rotating propeller will still develop thrust after separation and will tend to yaw to left or right depending upon its direction of rotation. For clockwise rotation, when viewed from the rear, the direction of yaw will be to the left and vice versa. Investigation confirmed that the propellers of the Twin Comanche rotate in a clockwise direction and the apparent incompatibility was resolved.

Two further problems are well illustrated by the in-flight break-up of Sabre A94-358 on 16th August, 1966, Fig. 6. The final position of a recovered item may not be identical with its ground impact point since it may bounce after impact. Some items, particularly wheels, may bounce a surprisingly long way after impact as illustrated by Fig. 6 which indicates the position of a nose wheel which finally came to rest some 140m (150 yds.) from its ground impact point. Other items may be recovered from positions which, apparently, defy rational explanation. The reported position of an aileron control rod and a tail fin piece shown in Fig. 6 are good examples. Either

these reported positions reflect ordinary human error, or the pieces were moved to their reported positions by some external agency. Despite wide publicity to the contrary, people still have a tendency to pick up odd pieces of wreckage and to carry them around for a while before discarding them.

## 7. DETERMINATION OF ALTITUDE

### 7.1 Light Wreckage Items

Experiments have indicated that light wreckage items fall with terminal velocities in the range 3-24 m/s (10-80 f.p.s.). It is commonly held that most wreckage items have terminal velocities of less than 15 m/s (50 f.p.s.), Ref. 2. This is equivalent to saying that most wreckage items are small and light which, in general, is true. However, this should not be interpreted to mean that the majority of the aircraft wreckage is contained in small light items since these items, although numerous, generally account for less than 10% of the aircraft weight.

The drift of light items, i.e. their distance from the break-up point measured along the line of the mean wind, must be a function of their terminal velocities. If the period of initial acceleration is ignored and all items are assumed to fall at their constant terminal velocities from break-up, then drift is given by,

$$\text{drift} = \frac{Av_w}{v_t} \tag{3}$$

where $A$ = altitude of break-up
$v_w$ = mean wind velocity
$v_t$ = terminal velocity

The constant ($Av_w$) is determined by assigning a terminal velocity of 3 m/s (10 f.p.s.) to the most distant item and 24 m/s (80 f.p.s.) to the item nearest the break-up point. Two values of ($Av_w$) are thus obtained and a mean value is usually acceptable but some weighing may be advisable in certain cases. These cases include those where the two values, as determined, are very different. This could indicate that no light items with a terminal velocity of 24 m/s (80 f.p.s.), in fact, existed or that, because of a large scatter of wreckage, the further boundary of the light items was not properly determined. The treatment of these cases is largely a matter of personal judgement and experience and it is difficult to provide hard and fast rules.

Once a value of ($Av_w$) has been established, then a scale of terminal velocity can be assigned to drift measured along the mean wind line. Using this scale, a terminal velocity can be assigned to any single light item. That is, instead of endeavouring to measure the terminal velocity of any individual light item, it is possible to estimate what its terminal velocity must have been by reference to its position along the drift line. Because of vagaries in the wind, this process in unlikely to be accurate; some individual items will have terminal velocities well above or below those estimated. Instead, it is better to consider the light items in groups and to estimate, for each group, a terminal velocity which is the average for the group as a whole. In effect, each group is replaced by a hypothetical item of wreckage which, in terms of drift and terminal velocity, represents the group as a whole. By this means, the vagaries associated with the trajectory of any individual light item are avoided while each item makes an equal contribution to the final calculation.

Frequently the groups are self-defined, i.e. there is a natural tendency for wreckage items to be associated in groups. Where these natural groups are ill-defined, a satisfactory approach is to divide the drift line into intervals and to consider the items in each interval as a group. The divison is arbitrary and selected so as to cater for such natural grouping as does exist.

Using equation (3), and assuming the wind velocity is known one estimate of altitude is obtained for each group and an example is contained in Fig. 7 and Table 1. For break-up at low altitude, these estimates may be corrected if desired, to allow for the period of initial acceleration. Based on the experimental data of Ref. 3, a useful rule-of-thumb correction is obtained by subtracting from the calculated altitude an amount equal to the distance covered in one second at the terminal velocity, i.e.

$$\text{corrected altitude} = v_t\left(\frac{\text{drift}}{v_w} - 1\right) \tag{4}$$

Generally, however, the corrections are too small to be of significance given the inevitable variation in the estimates obtained.

This procedure for estimating altitude is valid only if $v_t$ is assumed constant. However, for any wreckage item, $v_t$ will increase with altitude. Hence, this report is restricted to break up altitudes of less than 3000m (10,000 ft.) where the error in assuming $v_t$ constant is small. These altitude estimates are all derived from trajectories in the one plane, viz. the vertical plane through the line of mean wind. In order to improve the reliability of altitude estimates, it is desirable to use not only trajectories intersecting in one plane, but also trajectories in intersecting planes.

### 7.2 Heavy Wreckage Items

As mentioned earlier, heavy items lie close to the line marking the extended flight path of the aircraft. These items have high terminal velocities of up to 80 - 85 m/s (260 - 280 f.p.s.) and, unless the altitude is sufficiently great, will not achieve their terminal velocity before ground impact. Hence, the terminal velocity approach will not work for these items and a purely empirical approach is adopted based on a comparison with data obtained from Woomera trials. These data are expressed in terms of a factor ($S/S_0$) which is defined as the ratio of the achieved forward throw to the forward throw calculated for zero aerodynamic drag. Forward throw is measured from the break-up point along the extended flight path of the aircraft.

The values of $S/S_0$) of most interest are those applicable to the maximum ($S_H$) and minimum ($S_L$) limits of the heavy wreckage items. These values are shown in Fig. 8 for altitudes up to 3000m (10,000 ft.). Assuming $v_0$ is known, then $S_0$ can be determined as a function of altitude using the standard equations of motion for a vacuum. By using the data of Fig. 8, this relationship may be used to plot $S_H$ and $S_L$ as functions of altitude. The estimated altitude of break-up is then the altitude corresponding to the measured values of $S_H$ and $S_L$. Two estimates of altitude are thus obtained based on trajectories in the vertical plane passing through the extended flight path of the aircraft. Some caution is advisable in the interpretation of these results. The number of heavy wreckage items is, at times, insufficient to establish the spread of heavy items with accuracy. Usually $S_H$ can be established with confidence since all aircraft will produce high density items on which this is based, e.g. battery boxes, undercarriage legs, wheels, guns, etc. However, in estimating $S_L$ it is necessary to examine the data carefully for special features which may tend to give misleading results.

## 8. DISCUSSION

The procedures given in section 7 for the determination of altitude may also be used to determine aircraft speed if this is unknown. By using the altitude estimated from light items, ($S_H/S_0$) and ($S_L/S_0$) may be obtained directly from Fig. 8. Since $S_H$ and $S_L$ are known measurements, $v_0$ may then be determined. Equally, instead of using the heavy items to obtain two estimates of altitude or speed, they may be used to obtain one altitude estimate plus one speed estimate. The procedure is the same as given in Section 7 except that families of curves representing plots of $S_H$ and $S_L$ as functions of both speed and altitude are necessary. This requires a high level of confidence in the measured values of $S_H$ and $S_L$. Based on Woomera Trials data, the accuracy of results obtained using these procedures is estimated to be approximately ± 20%.

The procedures outlined in this paper fall short of scientific exactitude. They rely heavily on intuition and experience and it is not possible, given the current state of the art, to lay down hard and fast rules of procedure. Each step is basically a process of trial and error which is continued until a self-consistent picture has been obtained. Despite these short-comings a great deal of valuable information can be derived from aircraft wreckage layouts. Such information should be considered additional to, rather than substituting for, data obtained from more conventional sources such as the examination of fracture surfaces, instrument readings and eye witness reports. From the foregoing it is clear that this paper represents an interim statement only; a lot more work remains to be done.

## 9. CONCLUSIONS

By using the procedures outlined in this paper it is possible to establish the break-up point and to obtain some information on the break-up sequence. The altitude and speed of the aircraft at break-up can be determined with an accuracy of approximately ± 20%. As yet, the procedures are confined to altitudes of less than 3000m (10,000 ft.). Further extension of the procedures to encompass higher altitudes must await analysis of Woomera Trials conducted at medium and high altitudes.

## REFERENCES


| | | |
|---|---|---|
| 1. | — | Investigation of loss of Jindivik A92-413.<br>G.A.F. Project Note B44/65<br>June, 1965. |
| 2. | — | Manual of aircraft accident investigation.<br>I.C.A.O.<br>Third edition — 1959 |
| 3. | S.R. Gwilt | Trajectory analysis in aircraft accident investigation.<br>Aeronautical Report LR-310.<br>National Research Council of Canada October, 1961. |



Postal Address: Chief Superintendent
Aeronautical Research Laboratories,
P.O. Box 4331, Melbourne Vic. 3001

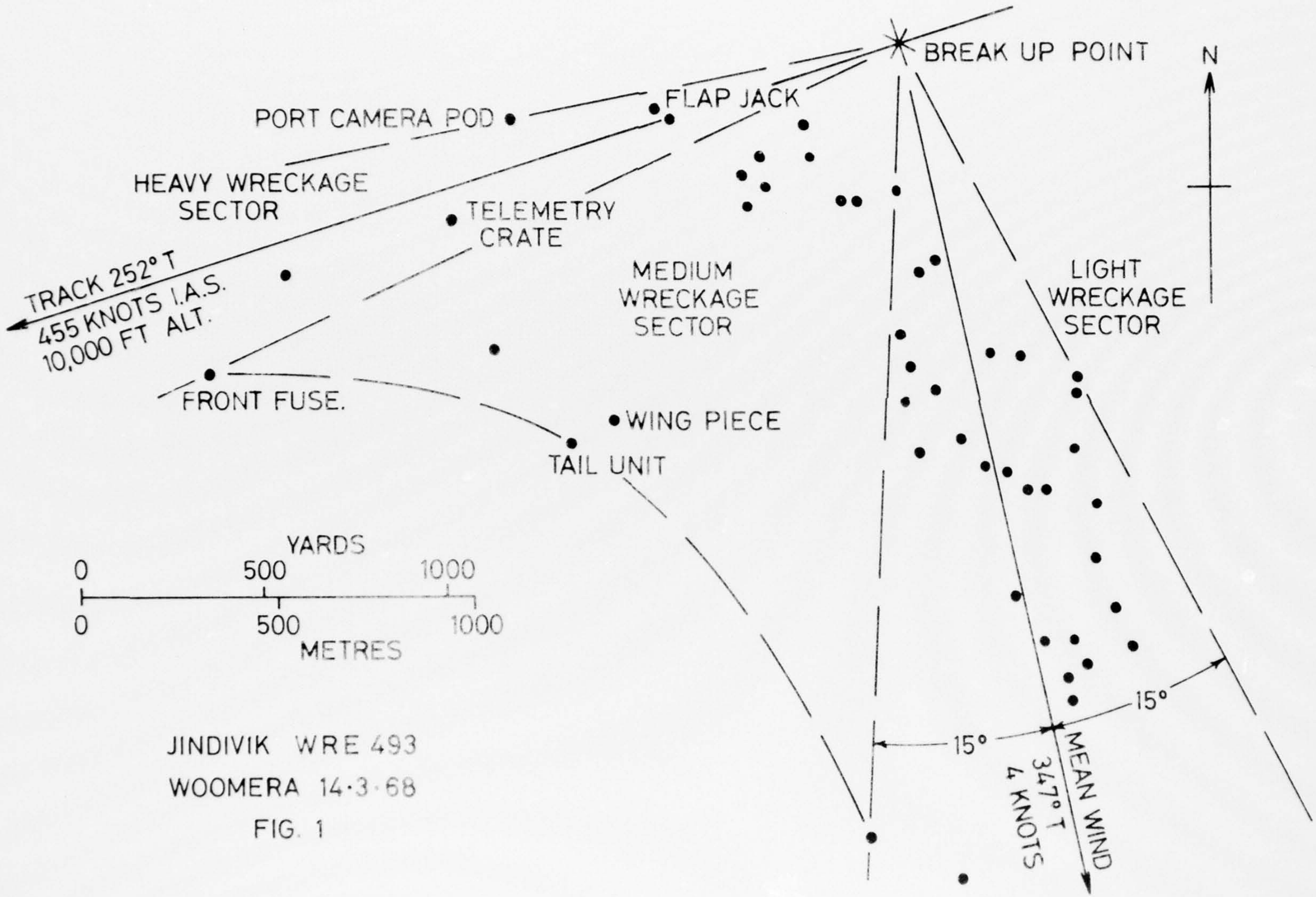
**TABLE 1**

**DETERMINATION OF ALTITUDE**
**JINDIVIK A92-90 — LIGHT WRECKAGE ITEMS**

| WRECKAGE GROUP | AVERAGE DRIFT | | TERMINAL VELOCITY | | ALTITUDE | |
|---|---|---|---|---|---|---|
| | Ft. | METRES | F.P.S. | M/S | Ft. | METRES |
| 1 | 4050 | 1235 | 70 | 21.35 | 8850 | 2700 |
| 2 | 8100 | 2470 | 50 | 15.25 | 12650 | 3860 |
| 3 | — | — | 35 | 10.68 | — | — |
| 4 | 12820 | 3910 | 27.5 | 8.38 | 11030 | 3360 |
| 5 | 16150 | 4930 | 22.5 | 6.86 | 11380 | 3470 |
| 6 | — | — | 17.5 | 5.34 | — | — |
| 7 | 25400 | 7750 | 12.5 | 3.81 | 9930 | 3030 |
| 8 | 33850 | 10300 | 10 | 3.05 | 10580 | 3220 |

**ALTITUDE** = 10750 ± 1900 Ft.
= 3280 ± 580 Metres

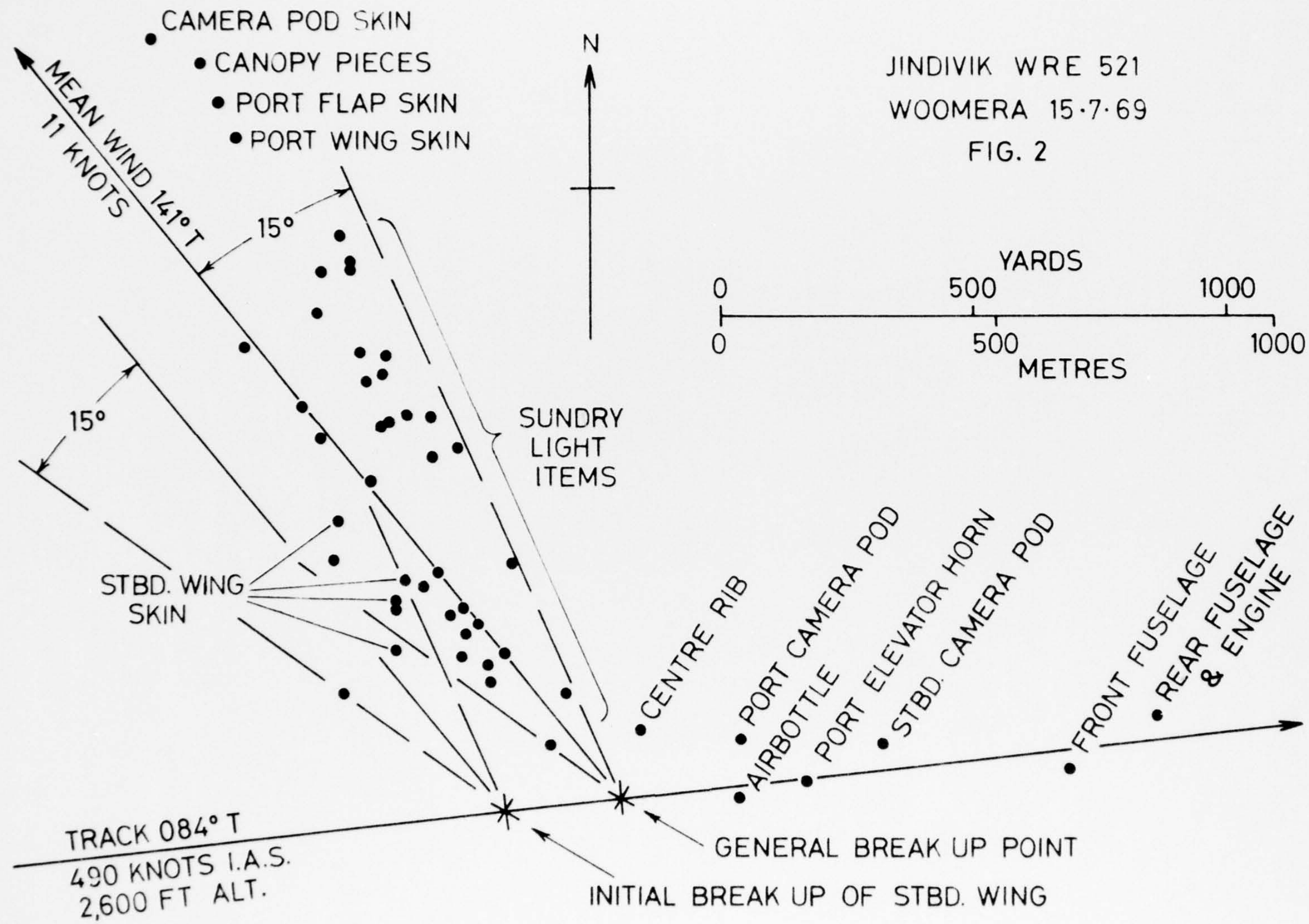
NOTE: Altitude estimates are not corrected for initial acceleration



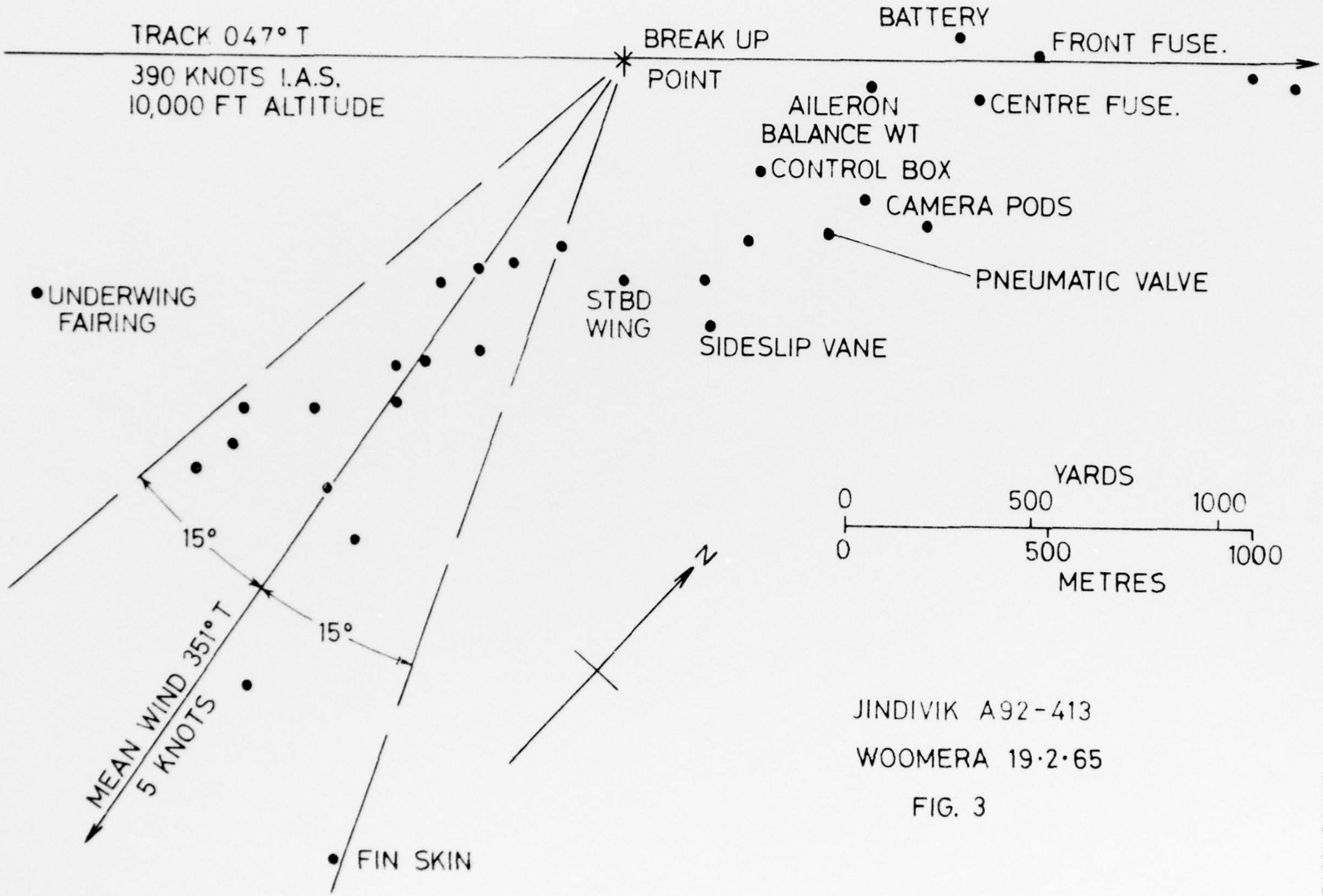

JINDIVIK WRE 493

WOOMERA 14·3·68

FIG. 1



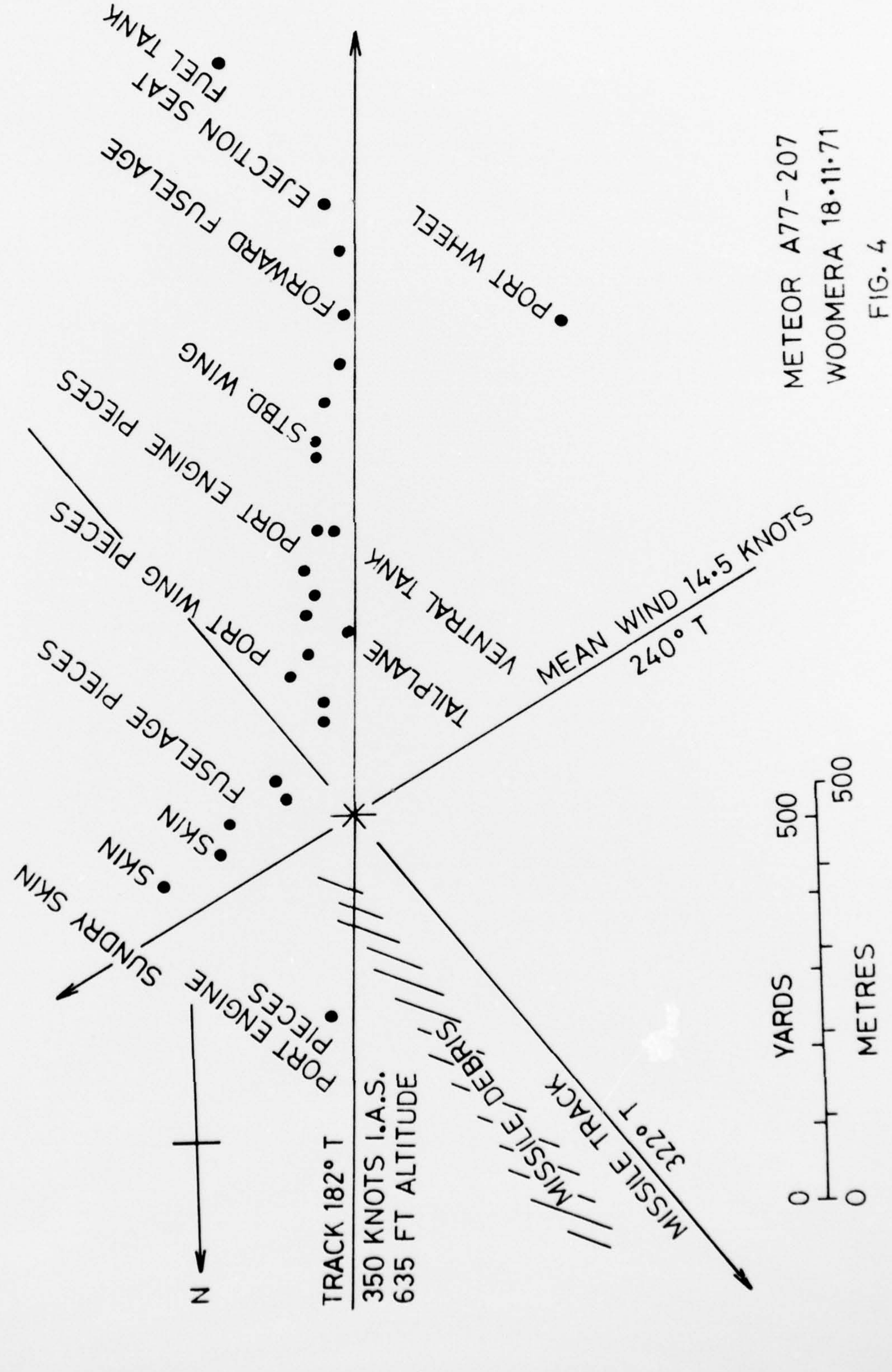

JINDIVIK WRE 521
WOOMERA 15·7·69
FIG. 2



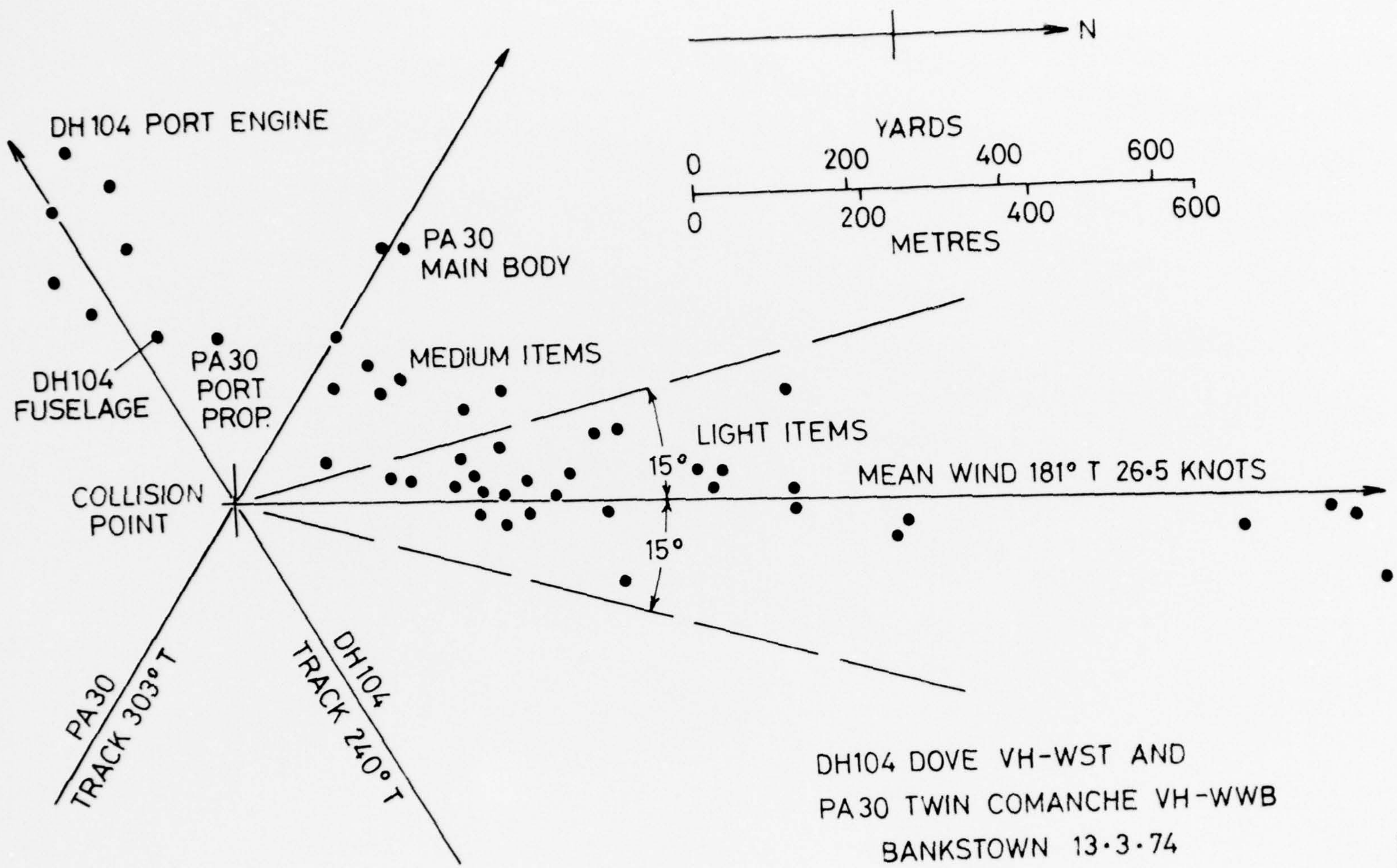

JINDIVIK A92-413

WOOMERA 19·2·65

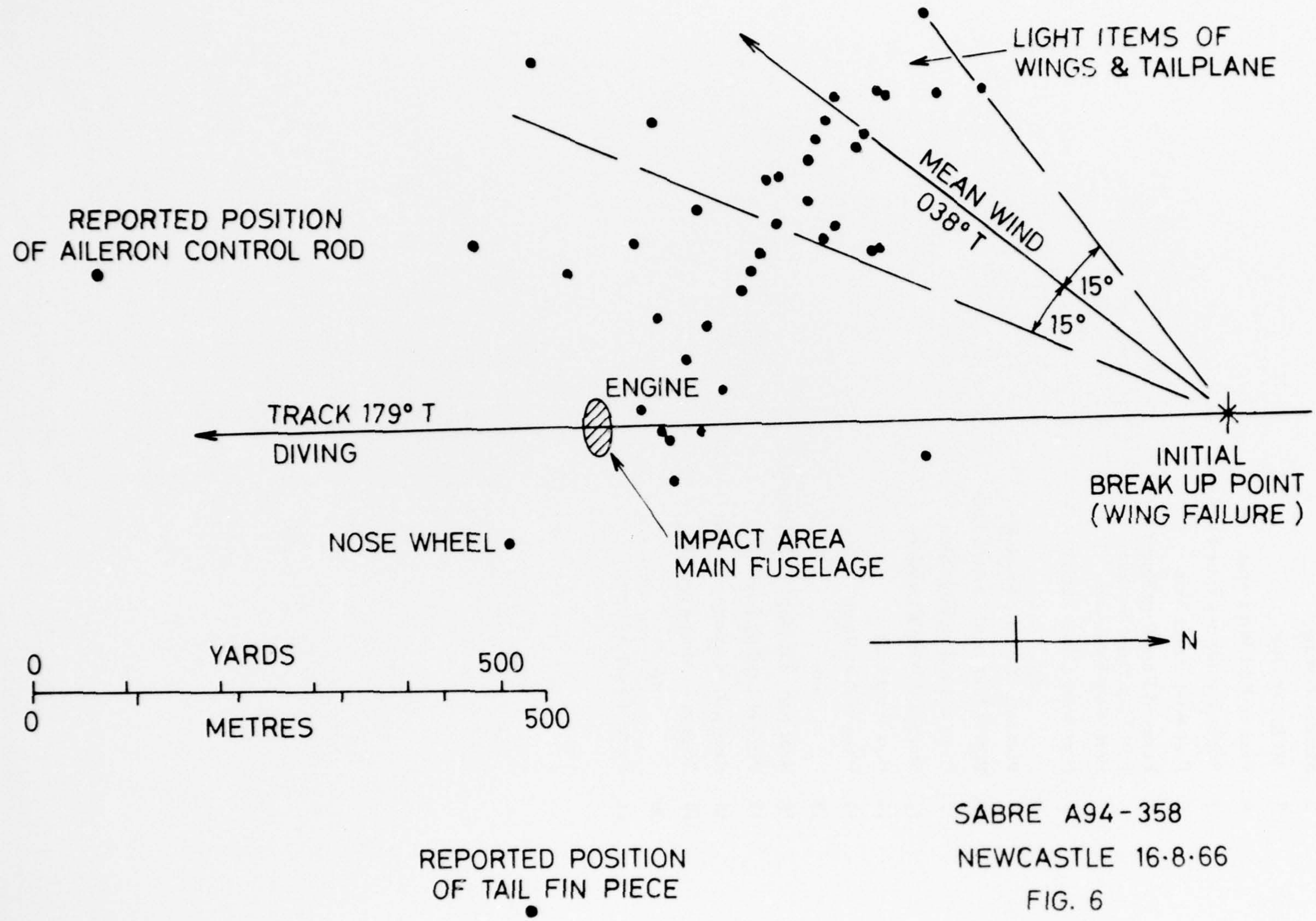
FIG. 3




METEOR A77-207
WOOMERA 18·11·71
FIG. 4




DH104 DOVE VH-WST AND
PA30 TWIN COMANCHE VH-WWB
BANKSTOWN 13·3·74
FIG. 5



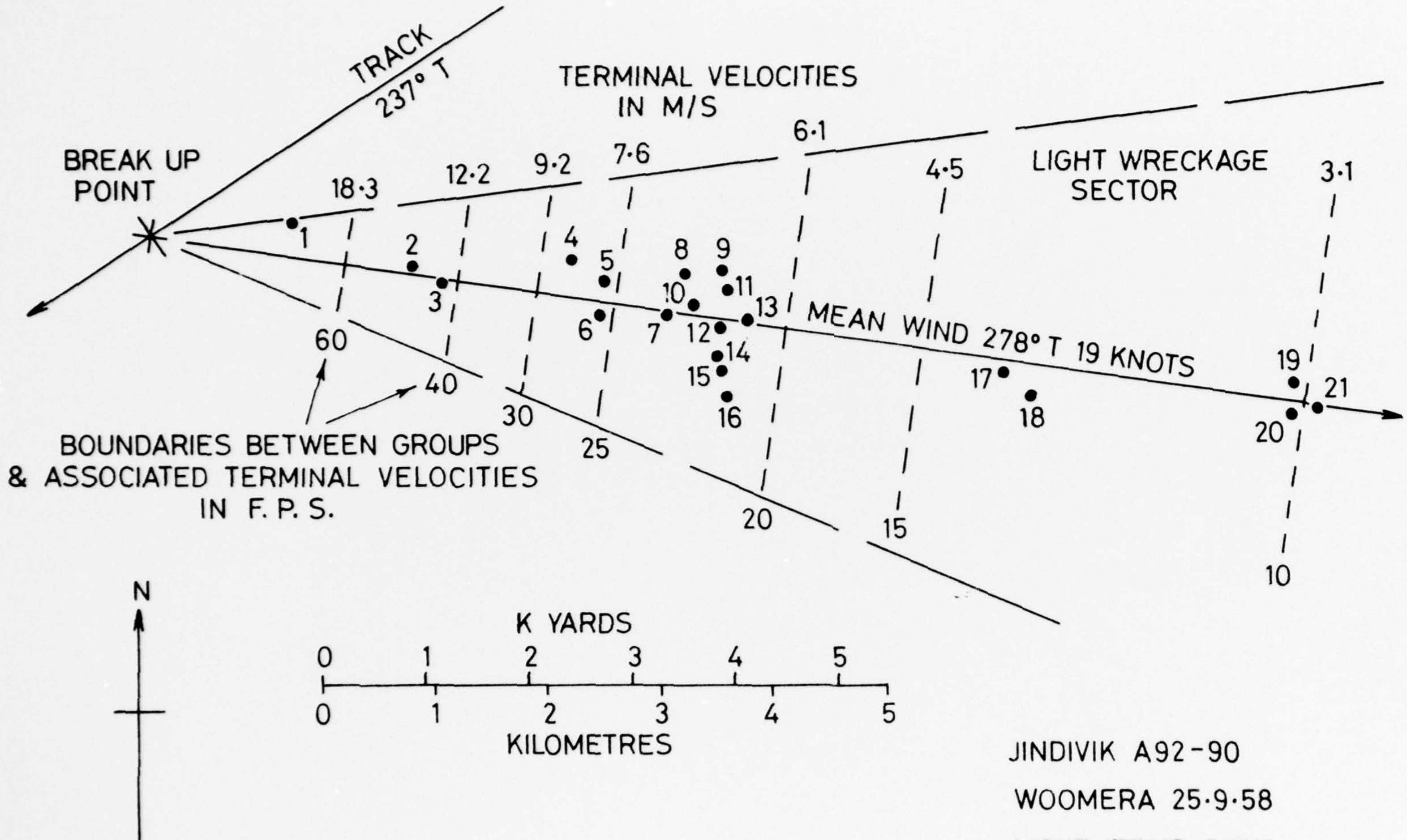

SABRE A94-358

NEWCASTLE 16·8·66

FIG. 6

**JINDIVIK A92-90**
**LEGEND**

1. Lower part of Fuselage Nose.
2. Starboard Wing.
3. Air Intake Duct.
4. Piece of Port Wing Spar
5. Starboard side of Centre Fuselage.
6. Port Wing Upper Skin.
7. Pieces of Port Wing Spar (2).
   Port Flap Outer Section.
   Port Wing Extension.
8. Port Wing Lower Skin.
9. do
   Port side of Centre Fuselage.
10. Port & Starboard Camera Pods.
11. Piece of Leading Edge Skin.
12. Starboard Wing Extension.
13. Port Wing Cuff.
14. Piece of Port Flap.
15. do
16. Rear part of Canopy — Starboard
17. Piece of Leading Edge Skin.
18. Rear part of Canopy — Port.
19. Piece of Leading Edge Skin.
20. do
21. Piece of Port Aileron.

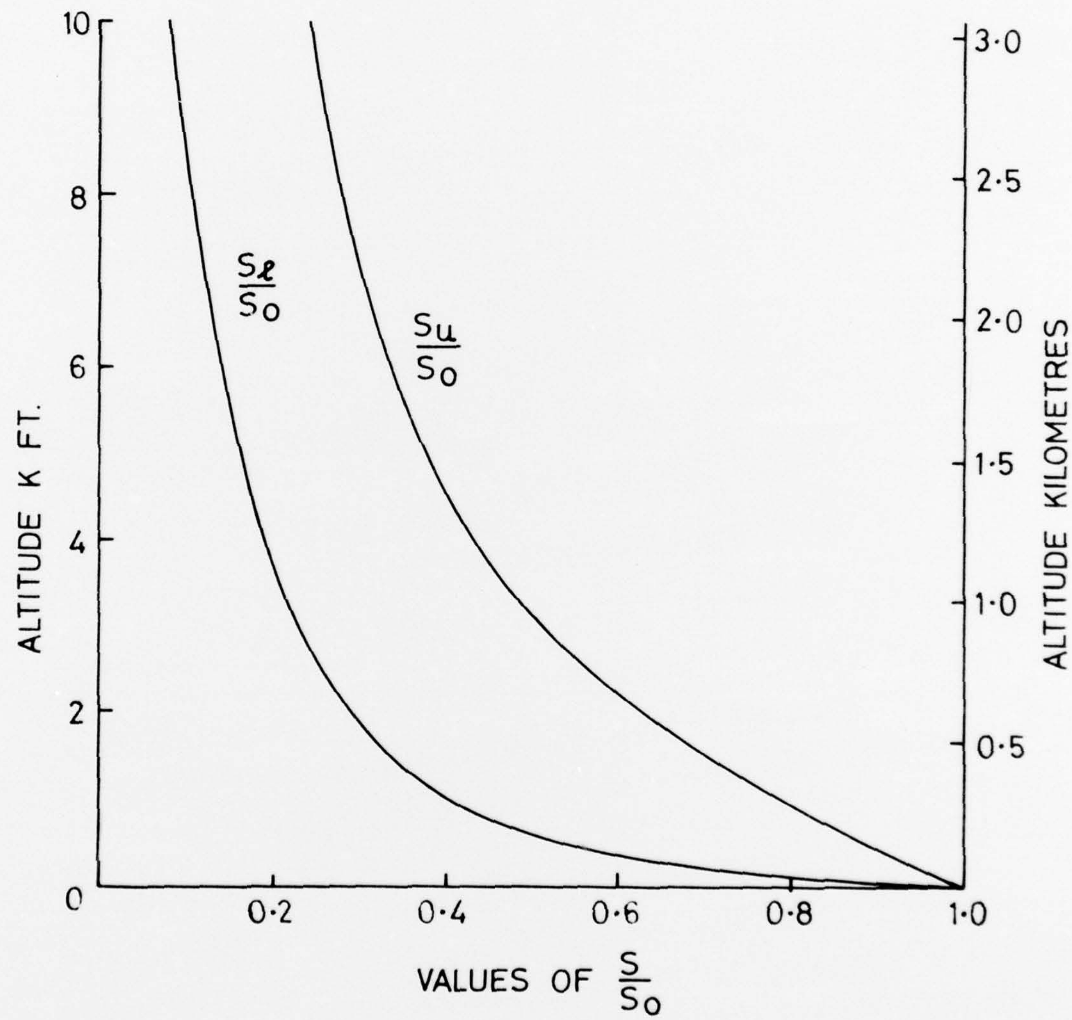



JINDIVIK A92-90

WOOMERA 25·9·58

LIGHT ITEMS ONLY

FIG. 7




FORWARD THROW OF HEAVY WRECKAGE ITEMS

FIG. 8

# DISTRIBUTION

| | | Copy No. |
|---|---|---|
| **AUSTRALIA** | | |
| **DEPARTMENT OF DEFENCE** | | |
| **Central Office** | | |
| Chief Defence Scientist | | 1 |
| Executive Controller, ADSS | | 2 |
| Superintendent | —Defence Science Administration | 3 |
| Controller | —Service Laboratories and Trials Division | 4 |
| Controller | —Military Studies and Operational Analysis Division | 5 |
| Controller | —Programme Planning and Policy Division | 6 |
| Central Library | | 7 |
| S.T.I.B. | | 8 |
| J.I.O. | | 9 |
| **Aeronautical Research Laboratories** | | |
| Chief Superintendent | | 10 |
| Superintendent, Structures Division | | 11 |
| Structures Divisional File | | 12 |
| J.L. Kepert (Author) | | 13 |
| B.C. Hoskin | | 14 |
| Library | | 15 |
| **Central Studies Establishment** | | |
| Library | | 16 |
| **Materials Research Laboratories** | | |
| Library, Victoria | | 17 |
| **Weapons Research Establishment** | | |
| Library | | 18 |
| **Air Office** | | |
| D. Air Eng. | | 19 |
| Air Force Scientific Adviser | | 20 |
| Library, Engineering (AMTS), Canberra | | 21-24 |
| S.T.S.O., Support Command, H.Q., | | 25 |
| Library, A.R.D.U., Laverton | | 26 |
| Director of Air Force Safety, Canberra | | 27-29 |
| **Army Office** | | |
| Army Scientific Adviser | | 30 |
| **Navy Office** | | |
| Naval Scientific Adviser | | 31 |
| **DEPARTMENT OF INDUSTRY AND COMMERCE** | | |
| **Government Aircraft Factory** | | |
| Library | | 32-33 |
| **DEPARTMENT OF TRANSPORT** | | |
| **Air Transport Group** | | |
| Director-General/Library | | 34 |
| Mr. R. Ferrari | | 35 |
| Director of Special Investigations | | 36-41 |

## STATUTARY AUTHORITIES AND INDUSTRY

| | | |
|---|---|---|
| Library, Qantas | | 42 |
| Library, Trans-Australia Airlines | | 43 |
| Library, Ansett Airlines of Australia | | 44 |
| Hawker de Havilland Pty. Ltd., (Tech. Librarian) Bankstown | | 45-46 |
| Hawker de Havilland Pty. Ltd., (Manager) Lidcombe | | 47 |
| Commonwealth Aircraft Corporation, (Manager) | | 48 |

## UNIVERSITIES

| | | |
|---|---|---|
| Sydney | Professor G.A. Bird, Aeronautics | 49 |
| **Royal Melbourne Institute of Technology** | | |
| | Library | 50 |
| | Aero. Eng. Dept. (Mr. H. Millicer) | 51 |

## CANADA

| | | |
|---|---|---|
| National Research Council of Canada, Library | | 52-53 |
| **Universities** | | |
| Toronto | Institute of Aerophysics | 54 |
| C.A.A.R.C. Co-ordinator Structures — Dr. G.R. Cowper | | 55 |

## FRANCE

| | |
|---|---|
| A.G.A.R.D. Library | 56 |
| O.N.E.R.A. | 57 |
| Service de Documentation et d'Information | 58 |

## INDIA

| | |
|---|---|
| Ministry of Defence, Aero. Development Establishment | 59 |
| Department of Civil Aviation, (Director) | 60 |
| National Aeronautical Laboratory, (Director) | 61 |
| C.A.A.R.C. Co-ordinator Structures — Professor P.N. Murthy | 62-66 |

## NETHERLANDS

| | |
|---|---|
| N.L.R. Amsterdam | 67 |

## NEW ZEALAND

| | |
|---|---|
| Air Department, R.N.Z.A.F., Aero. Documents Section | 68 |
| Department of Transport, Library | 69 |

## SWEDEN

| | |
|---|---|
| Aeronautical Research Institute | 70 |

## UNITED KINGDOM

| | |
|---|---|
| Defence Scientific and Technical Representative, London | 71 |
| Defence Research Information Centre | 72-73 |
| Aeronautical Research Council, N.P.L. (Secretary) | 74-75 |
| C.A.A.R.C. N.P.L. (Secretary) | 76 |
| Royal Aircraft Establishment, Library, Farnborough | 77-78 |
| Royal Aircraft Establishment, (O.I.C. Accident Investigation Group) Farnborough | 79 |
| C.A.T.C. (Secretariat) | 80 |
| C.A.A.R.C. Co-ordinator Structures — Mr. A.J. Sobey, R.A.E. | 81 |
| Accidents Investigation Branch, Dept. of Trade | 82 |
| **Aircraft Companies** | |
| Hawker Siddeley Aviation Ltd., Brough | 83 |

## DOCUMENT CONTROL DATA

| | |
|---|---|
| 1. Security Grading/Release Limitation<br>(a) Document Content : Unclassified<br>(b) This Page : Unclassified | 2. Document Type/Number<br>Structures Note 427<br>3. Document Date<br>May 1976 |
| 4. Title and Sub-title<br>THE USE OF WRECKAGE TRAJECTORIES IN AIRCRAFT ACCIDENT INVESTIGATION | |
| 5. Personal Author: J.L. Kepert<br>6. Corporate Author(s): Aeronautical Research Laboratories | |
| 7. Abstract<br>*This paper examines the characteristics of aircraft wreckage layouts obtained after an in-flight break-up and discusses the use of these data in accident investigation.*<br>*Procedures are developed for the determination of some relevant parameters such as the position and altitude of break-up. The paper mentions some of the problems which may be encountered and emphasises that the analysis of aircraft wreckage trajectories should be considered additional to, rather than a substitute for, more conventional accident investigation techniques.* | |
| 8. Computer Program(s) — Titles and Languages | |
| 9. Descriptors<br>Aviation Accidents<br>Accident Investigations | 11. Cosati Classifications<br>0102, 1402<br>12. Task Reference (RD/P)<br>RD 70 |
| 10. Library Distribution (Defence Group)<br>Central Library<br>S.T.I.B.<br>J.I.O.<br>A.R.L.<br>M.R.L. C.S.E. W.R.E.<br>(Air Office) (AMTS) Canberra<br>A.R.D.U. (Laverton) | 13. Sponsoring Agency Reference<br>50/2<br>14. Cost Code<br>21 1020 |
| 15. Imprint<br>Melbourne — Aeronautical Research Laboratories — 1976 | |